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[54] **MAGNETIC DRIVE**

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[51] **Int. Cl.**[6] **F04B 17/00**

[52] **U.S. Cl.** **417/420**; 417/53

[58] **Field of Search** 417/420, 423.12, 417/53; 416/3

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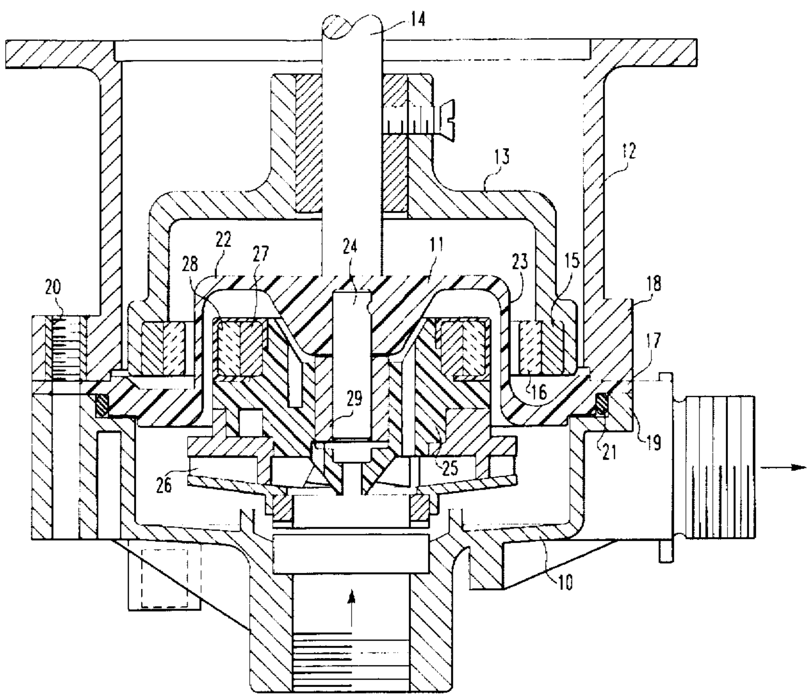
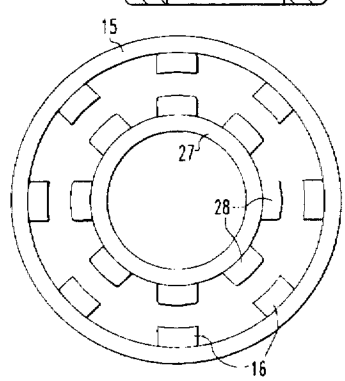
[57] **ABSTRACT**

A magnetic drive comprises a plurality of identically shaped and sized permanent magnets for transmitting torque to a shaft through a nonmagnetic cylindrical barrier wherein the magnets have inner and outer cylindrical surfaces with the outer cylindrical surfaces having a radius substantially the same as the inner cylindrical surfaces.

8 Claims, 4 Drawing Sheets





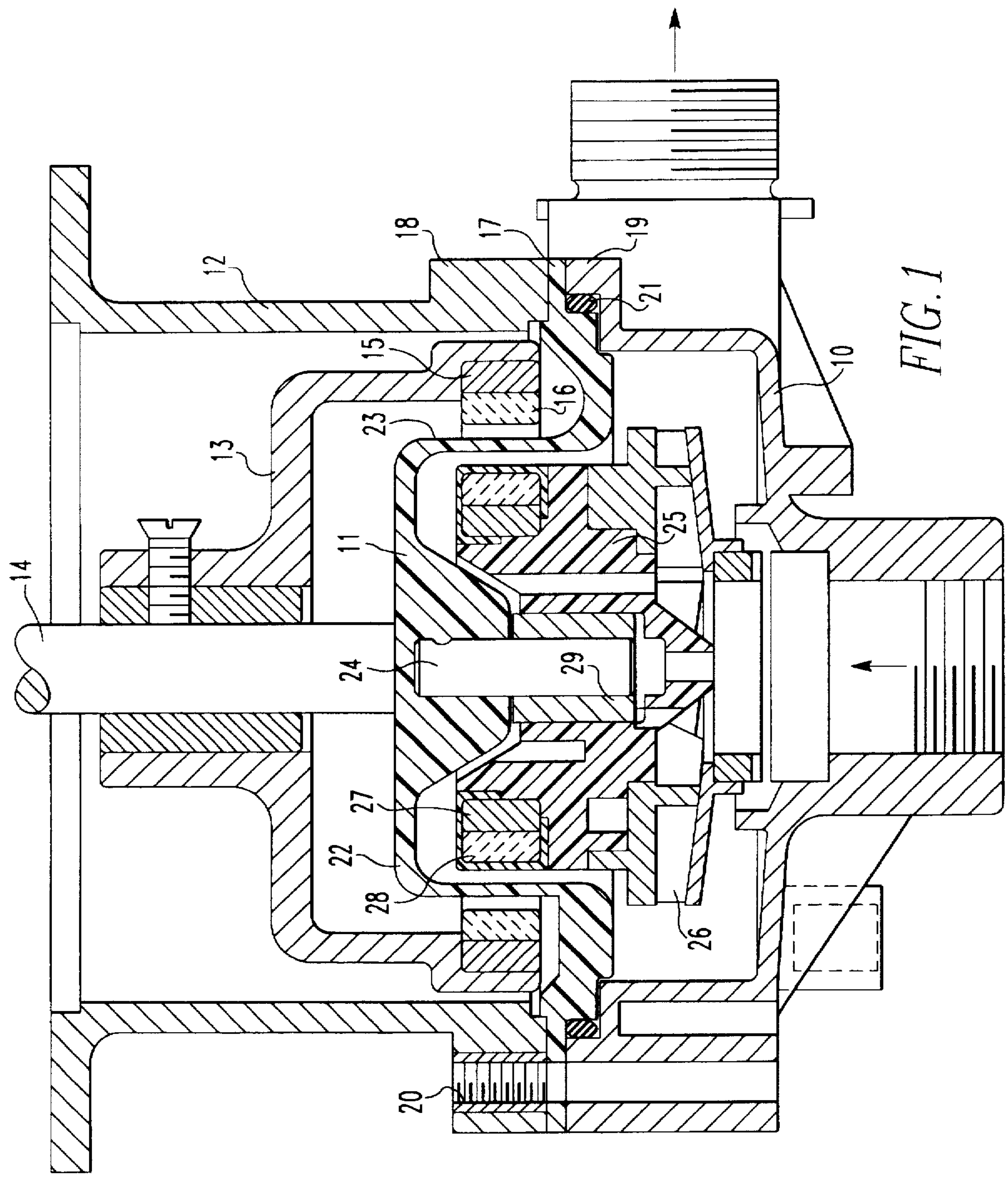


FIG. 1

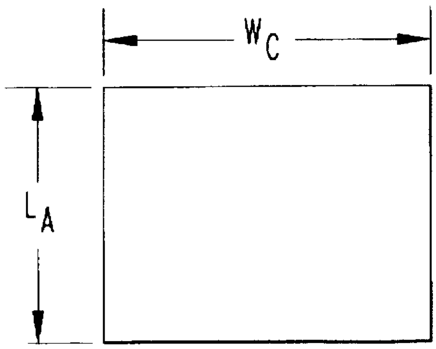


FIG.2A

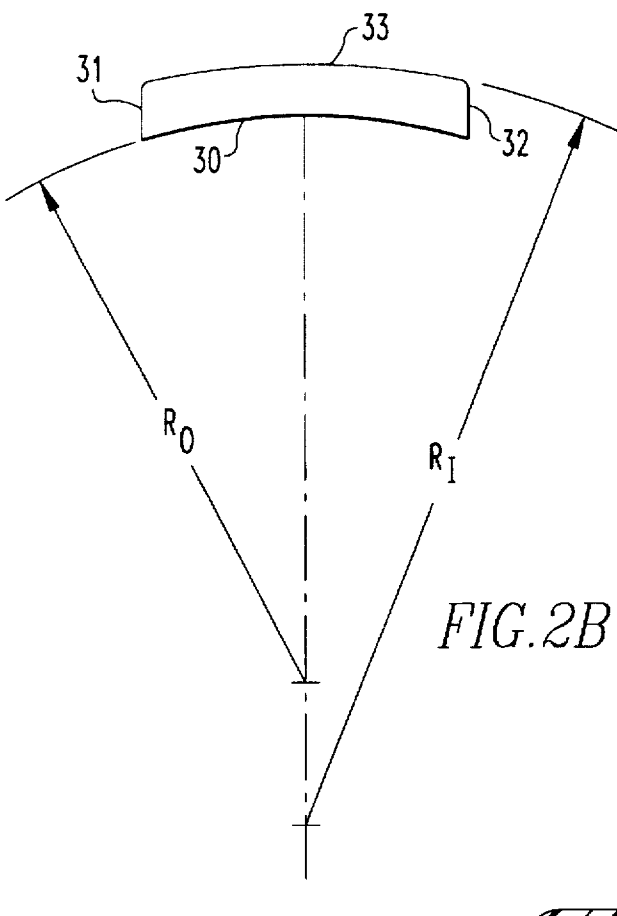


FIG.2B

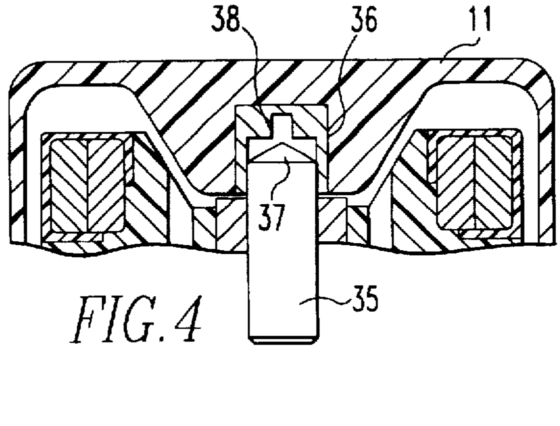


FIG.4

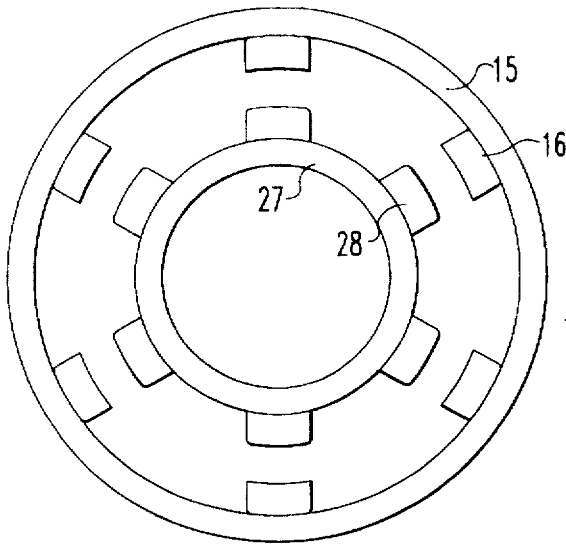


FIG. 3A

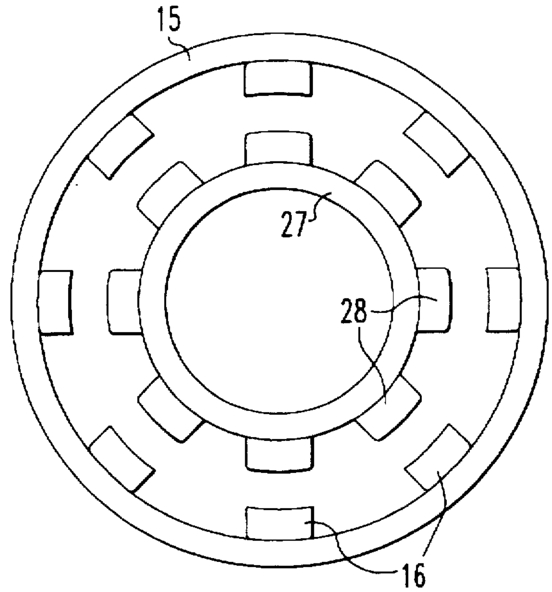


FIG. 3B

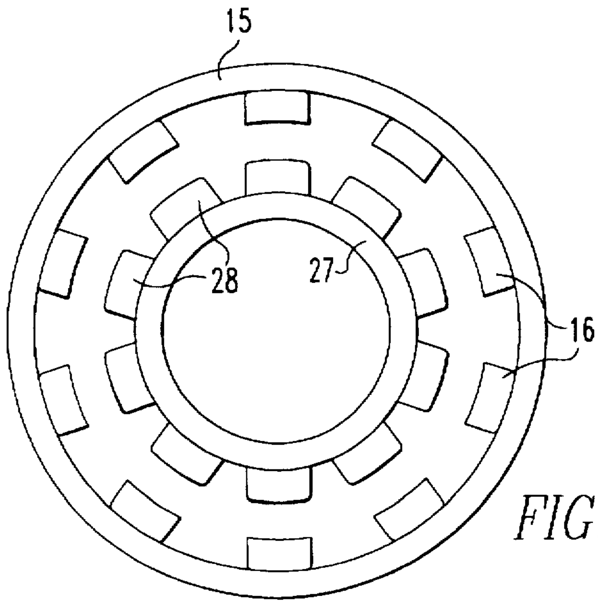


FIG. 3C

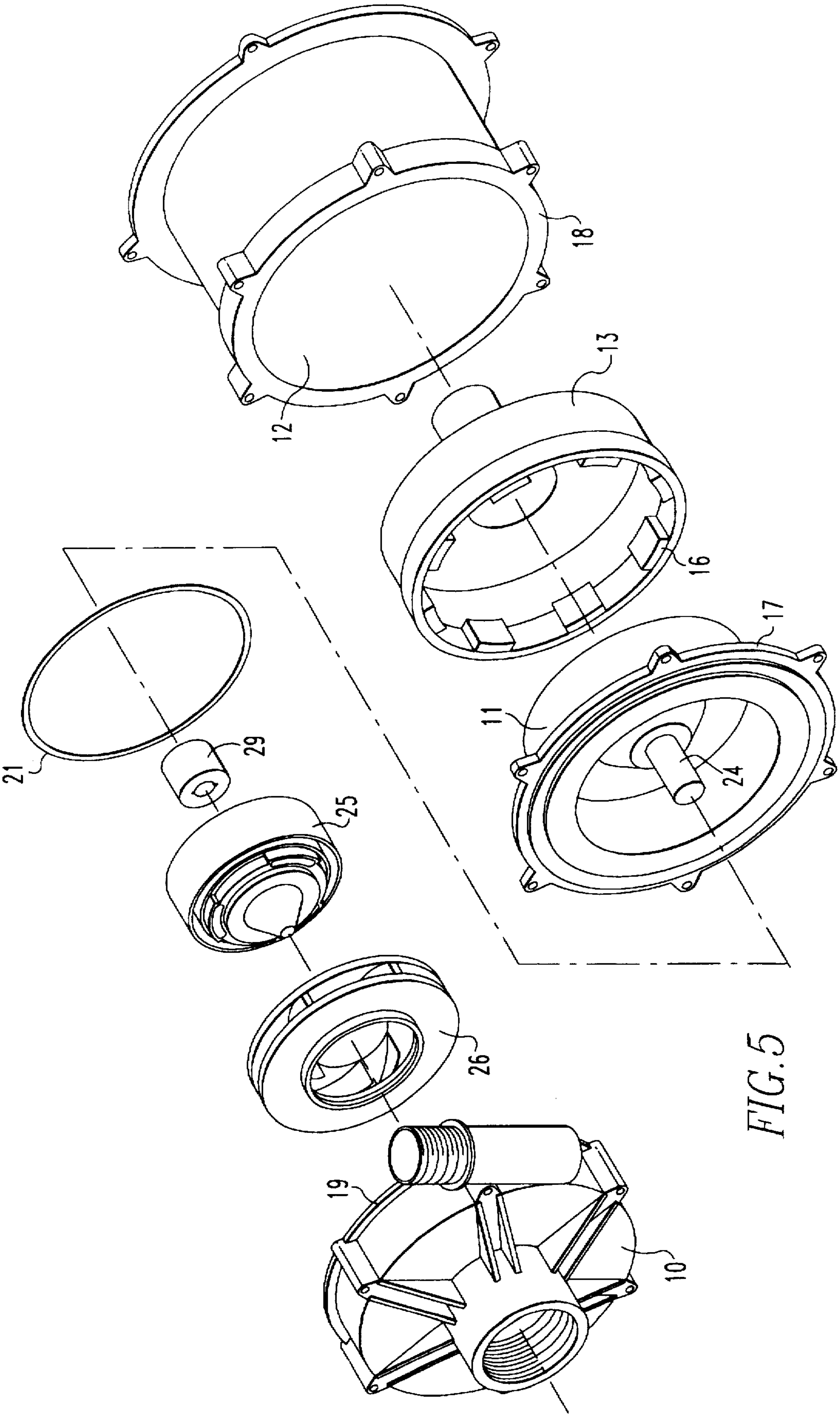


FIG.5

MAGNETIC DRIVE

BACKGROUND OF THE INVENTION

This invention relates to an improved magnetic drive for use in transfer of torque to corrosive or pressurized environments. Magnetic drives are known for transferring torque through nonmagnetic barriers, especially for pumping or stirring liquids on the interior of a sealed enclosure.

Most commercial pump suppliers are required to offer a line of products to customers having a range of maximum torque transfer capability. In the past, this has meant that the overall size of the products had to be increased as the maximum torque transfer capability was increased, resulting in a different set of parts for each product or pump in the line of products. Thus, manufacturers of magnetically driven pumps have found it necessary to purchase or manufacture magnets of many sizes. Typically, the magnets must have increased axial length as the need for increased torque was required. Also, the driving magnets and the driven magnets for each size pump had different shapes or configurations.

This patent application is based upon a unique application of the more powerful permanent magnets that have become available in the last several years. The strength of permanent magnets (as measured by energy products $(BH)_{max}$) has rapidly increased in recent years. Approximate strengths for each type of permanent magnet is set forth in the following table.

MATERIAL	ENERGY PRODUCT $(BH)_{max}$ MGOe(kJ/m^3)
Ceramic (Ferrite)	4 (32)
Alnico	12 (95)
Samarium Cobalt ($SmCo_5$)	18 (143)
Samarium Cobalt (Sm_2Co_{17})	27 (215)
Neodymium Iron Boron (Nd—Fe—B)	35 (280)

In this patent application, we will refer to the samarium cobalt (either) and the neodymium iron boron magnets as rare earth magnets. The rare earth magnets offer the possibility of a radical new approach to design of magnetic couplings that transfer torque. Unless high temperatures are likely, the neodymium iron boron magnets are the preferred rare earth magnets for the practice of this invention.

It is an advantage, according to this invention, to construct a magnetic drive with magnets of the rare earth type having a single size and shape used on both the driving and driven magnet assemblies.

It is a further advantage of this invention to construct a series of magnetic drives having different maximum torque carrying capacities using magnets of the rare earth type having a single size and shape in both the driving and driven magnet assemblies of all magnetic drives in the series.

It is yet a further advantage, according to this invention, that the need for thrust bearings can be eliminated in the magnetic drives in many applications.

It is a further advantage, according to this invention, to provide a magnetically driven pump or series of magnetically driven pumps wherein the magnets have a single size and shape on both the driving and driven magnet assemblies for all pumps in the series.

SUMMARY OF THE INVENTION

Briefly, according to this invention, there is provided a magnetic drive comprising a plurality of identically shaped and sized permanent magnets for transmitting torque to a shaft through a nonmagnetic cylindrical barrier. The magnetic drive comprises a first assembly positioned to rotate outwardly of the cylindrical barrier, said assembly having a ferromagnetic outer ring with an inner radius RI. The magnetic drive further comprises a second assembly positioned to rotate inwardly of the cylindrical barrier having a ferromagnetic inner ring with an outer radius RO. The first and second assemblies have an identical number of circumferentially spaced permanent magnets spaced around the rings. The magnets have an inner and outer cylindrical surface. The outer cylindrical surface has a radius substantially the same as the inner radius RI of the outer ring and the inner cylindrical surface has a radius substantially the same as the outer radius RO of the inner ring. Preferably, the axial dimension of the cylindrical faces of the magnets and the circumferential dimension are substantially equal. Preferably, the magnets are radially magnetized and an even number of magnets are spaced about each ring with alternating polarities. Preferably, the magnets are of the rare earth type and particularly are of the samarium cobalt or the neodymium iron boron type.

In a preferred embodiment, a magnetically driven pump is provided which comprises an impeller chamber and an impeller positioned to rotate in the chamber mounted on a shaft. The magnetic drive comprises a first ferromagnetic ring positioned to rotate outwardly of a cylindrical barrier and a second ferromagnetic ring positioned to rotate inwardly of the cylindrical barrier. The second ring is connected to the impeller. The first and second rings can be transposed and still achieve the same function. The first and second rings have an even number of circumferentially positioned permanent magnets as above described.

There is also provided, according to this invention, a method of making a series of magnetic drives with different maximum torque capacities from parts having identical dimensions. The method comprises assembling a plurality of identically shaped permanent magnets, a nonmagnetic cylindrical barrier, an outer ring positioned to rotate outwardly of the cylindrical barrier and an inner ring positioned to rotate inwardly of the cylindrical barrier. The identically sized and shaped magnets are circumferentially spaced about the first and second rings in pairs with opposite magnetic polarity. The only difference between magnetic drives of different maximum torque capacity is the number of pairs of permanent magnets spaced around the inner and outer rings.

BRIEF DESCRIPTION OF THE DRAWINGS

Further features and other objects and advantages will become clear from the following detailed description made with reference to the drawings.

FIG. 1 is a section through a magnetically driven pump incorporating a magnetic drive according to this invention;

FIG. 2A is a top view of magnets according to this invention;

FIG. 2B is a side view of magnets according to this invention;

FIGS. 3A, 3B and 3C are schematic drawings of ferromagnetic rings and magnets according to this invention illustrating how one size and shape of magnet can be used to construct magnetic drives having different maximum torque transfer capabilities;

FIG. 4 is a section similar to that shown in FIG. 1 wherein the driven magnetic assembly is fixed to a shaft that is axially slidable in a bushing; and

FIG. 5 is an exploded pictorial view of a pump having a magnetic drive according to this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. **1** and **5**, there is illustrated in section a magnetically driven pump. A pump casing **10**, nonmagnetic barrier **11** and standoff **12** are assembled together to define two chambers sealed from each other. The pump casing **10** and nonmagnetic barrier **11** define the impeller chamber and a chamber for accommodating a driven magnet assembly attached to the impeller. The standoff and nonmagnetic barrier define a chamber for a driving magnetic assembly. The standoff **12** is typically attached to a motor (not shown).

A driving magnet assembly **13** is positioned within the standoff **12** and is secured to the drive shaft **14** of the motor. The body of the driving magnet assembly has an inverted (as shown in the drawing) cup shape with a ferromagnetic (for example, steel) ring **15** around the rim. Secured to the inside of the ring are a plurality of permanent magnets **16** of the rare earth type.

The nonmagnetic barrier has radial flanges **17** which are captured between a radial flange **18** on the standoff **12** and a radial flange **19** on the pump casing. The three radial flanges are clamped by bolts (not shown) passing through holes provided in the flanges **17** and **19** and engaging threads **20** provided in flange **18**. An O-ring **21** squeezed between the flanges seals the impeller chamber.

The nonmagnetic barrier has an inverted cup portion **22** which nests inside of the driving magnet assembly. The inverted cup has a cylindrical wall **23** with an axis that substantially coincides with the axis of the shaft **14**. A cylindrical pin **24** is fixed to the nonmagnetic barrier. The axis of the pin **24** also substantially coincides with the axis of the motor shaft **14**.

A driven magnet assembly **25** has a bushing **29** journaled on the pin **24**. Attached to the front of the driven magnet assembly is the impeller **26**. The driven magnet assembly **25** has a ferromagnetic ring **27** mounted therein. Secured on the outer cylindrical face of the ring **27** are a plurality of permanent magnets **28** of the rare earth type. The ring **27** and magnets **28** are encapsulated in a nonmagnetic resin to protect them from attack by corrosive liquids in the impeller chamber. The driven magnet assembly **25** slides axially along the pin **24** as well as rotates on the pin. The inner and outer magnetic ring assemblies can be transposed without affecting the function or embodiments of this invention. The magnets in the driven magnet assembly are positioned so that with a slight axial movement of the assembly, they can align with the magnets in the driving magnet assembly. No thrust bearings are required as the attraction between the two sets of rare earth magnets will hold the axial position of the driven magnet assembly and impeller.

The ferromagnetic ring **15** in the driving magnet assembly **13** has an inner cylindrical surface having a radius of curvature R_I. The ferromagnetic ring **27** in the driven magnet assembly has an outer cylindrical wall having a radius of curvature R_O. Referring now to FIG. **2**, the permanent magnets **16**, **28** all have an identical shape and size. The magnets have two cylindrical faces, an outer face having a radius R_I to match the inner cylindrical surface of the ring **15** in the driving magnet assembly and an inner face having a radius of curvature R_O to match the outer cylindrical surface of the ring **27** in the driven magnet assembly. Preferably, the center of curvature of both cylindrical surfaces lies on the same line extending through an axial line bisecting the circumferential width of the inner face **30** and outer face **33** of the magnets. The axial length L_A of the magnet faces and the circumferential width W_C of the inner magnet face **30** are in a ratio from about $L_A/W_C=1.5:1$ to $L_A/W_C=1:1.5$.

The thickness of the magnets in the radial direction varies. The magnets are thickest near the circumferential end walls **31** and **32**. Preferably, the edge of the circumferential end walls are rounded. This minimizes chipping and, in the case of the edges along the outer face **33**, reduces the possibility that the encapsulating coating on the driven magnet assembly will be cut by the edges and come apart from the assembly exposing the magnets.

As should now be apparent, the inner face **30** of the magnets can lie flush against the ring **27** and the outer face **33** of the magnets can lie flush against the ring **15**. This has been achieved by permitting the gap between the magnets on the ring **27** and the magnets on the ring **15** to be variable.

While the shape and size of all magnets are identical, the magnets are made in two sets, one magnetized north pole toward the radius of curvature of the faces (inward) and the other set magnetized north pole away from the radius of curvature of the faces (outward). Each ring has an even number of magnets equally spaced around the circumference thereof with magnets having opposite polarity alternating. The magnets may be installed using a jig that establishes the correct spacing. The magnetic attraction holds the magnets temporarily in place until an adhesive permanently secures the magnets to the rings.

One of the advantages of the magnetic coupling described above is the torque transfer capability can be increased or decreased with no need to increase the number of different parts. Referring now to FIGS. **3A**, **3B** and **3C**, there is shown the arrangement of the rings **15** and **27** and the magnets **16**, **28** for three different maximum torque levels. In FIG. **3A**, six pairs of magnets are arranged around the rings, in FIG. **3B** eight pairs and in FIG. **3C** ten pairs. The same identically sized and shaped magnets are used in all three arrangements. Going from the arrangement shown in FIG. **3A** to that shown in FIG. **3B**, maximum torque is increased about 35% and going from the arrangement **3B** to the arrangement of FIG. **3C**, the maximum torque is increased about 25%. These changes are possible without the need to make magnets of different sizes.

FIG. **4** illustrates an embodiment of this invention similar to that illustrated and described with reference to FIG. **1** except that the driven magnet assembly is fixed to the pin **35** and the pin **35** slides axially in a bushing **36** mounted in the nonmagnetic barrier **11**. The end **37** of the pin **35** may have a cone shape. The bushing **36** may have a reduced radius section **38** that the apex of the cone-shaped end of the pin can enter. If the axial forces on the driven magnetic assembly overcome the axial restraining forces of the magnets, the cone-shaped end will contact the bushing along a ring of contact minimizing the heat that would be generated due to friction.

The driving and driven magnet assemblies preferably are molded from a strong and tough plastic. In this way, the assemblies channel the magnetic flux through the magnets, the ferromagnetic rings and the gap between the aligned magnets. The magnetic barrier should be strong and tough plastic, brass or nonmagnetic stainless steel, for example.

Having thus described our invention with the detail and particularity required by the Patent Laws, what is desired protected by Letters Patent is set forth in the following claims.

We claim:

1. A magnetic drive comprising a plurality of permanent magnets for transmitting torque to a shaft through a nonmagnetic cylindrical barrier comprising:

a first assembly positioned to rotate outwardly of the cylindrical barrier, said assembly having a first ferromagnetic ring with an inner radius RI;

a second assembly positioned to rotate inwardly of the cylindrical barrier, said assembly having a second ferromagnetic ring with an outer radius RO;

the first and second assemblies having an identical number of circumferential positions for receiving permanent magnets, said plurality of permanent magnets bonded at said circumferential positions;

all said magnets, whether bonded on the first or the second assembly, being identically sized and shaped;

said magnets having inner and outer cylindrical surfaces, the outer cylindrical surface having a radius substantially the same radius as the inner radius RI of the first ferromagnetic ring and the inner cylindrical surface having a radius substantially the same as the outer radius RO of the second ferromagnetic ring.

2. The magnetic drive according to claim **1**, having axial dimensions and circumferential dimensions and wherein the axial and circumferential dimensions of the cylindrical faces of the identically shaped rare earth permanent magnets are substantially equal.

3. The magnetic drive according to claim **1**, wherein the identically shaped magnets are radially magnetized.

4. The magnetic drive according to claim **1**, wherein said first assembly comprises means for driving the first ferromagnetic ring.

5. The magnetic drive according to claim **1**, wherein the magnets are comprised of the rare earth type magnets, for example, of the samarium cobalt and the neodymium iron boron type magnets.

6. The magnetic drive according to claim **1**, wherein an even number of magnets are spaced around the circumference of the inner and outer cylindrical surfaces of said rings and the magnets are alternately radially magnetized toward and away from the cylindrical axis.

7. A magnetically driven pump comprising an impeller chamber, an impeller positioned to rotate in said chamber, a

magnetic drive comprising a nonmagnetic cylindrical barrier, a first ring positioned to rotate outwardly of a cylindrical barrier, said first ring having an inner radius RI, a second ring positioned to rotate inwardly of the cylindrical barrier, said second ring having an outer radius RO, the first and second rings having an identical number of circumferential positions for receiving permanent magnets, a plurality of permanent magnets bonded at said circumferential positions, all said magnets whether bonded on the first or the second assembly being identically sized and shaped, said magnets having inner and outer cylindrical surfaces, the outer cylindrical surface having a radius substantially the same as the inner radius RI of the first ring and the inner cylindrical surface having a radius substantially the same as the outer radius RO of the second ring, means for connecting the first ring to a drive, and means for connecting the second ring to the impeller.

8. A method of making a series of magnetic drives with different maximum torque capacities from parts having identical dimensions comprising the steps for assembling a plurality of identically sized and shaped permanent magnets, a nonmagnetic cylindrical barrier, a first ring positioned to rotate outwardly of the cylindrical barrier, said first ring having an inner radius RI, a second ring positioned to rotate inwardly of the cylindrical barrier, said second ring having an outer radius RO, the first and second rings having an identical number of circumferential positions for receiving permanent magnets, said plurality of identically sized and shaped permanent magnets bonded at said circumferential positions, said magnets having inner and outer cylindrical surfaces, the outer cylindrical surface having a radius substantially the same as the inner radius RI of the first ring and the inner cylindrical surface having a radius substantially the same as the outer radius RO of the second ring, such that the only difference between magnetic drives of different maximum torque capacities is the number of pairs of permanent magnets spaced around the inner and outer rings.

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